Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 23 (2011) 296 – 302

Procedia Engineering

www.elsevier.com/locate/procedia

PEEA2011

Research on Information Integration for Multidisciplinary Collaborative Design of Complex Customized Product

Liu Haiqiang[a], Chen Guojin[a,]a*

[a]*Department of Mechanical Engineering Hangzhou Dianzi University,Hangzhou,Zhejiang Province,China,310018*

Abstract

With customer and market diversification of complex customized product demand challenging to modern enterprises, the design process of product is continually confronted with various complicated design information. In this paper, the integration technology of information in the process of Multidisciplinary collaborative design (MCD) was discussed to shorten product delivery cycle, reduce overall costs and improve product quality. Firstly, a detailed description of the organization structure and modeling process of MCD-oriented Integration of Product Design Meta-model was given; secondly, the process integrated control method based on MCD-oriented Integration of Product Design Meta-model was proposed; finally, this method was validated by using application example.

Keyword: Multidisciplinary Collaborative Design; Design Process;Meta-model;Implementation method

1. Introduction

As the result of increasing market competition and popularization of information technologies, network technologies enables customers to quickly obtain information from the global market, customers now demand the product not only with high quality, and also hope that price remain virtually steady, and product delivery cycle can be as short as possible. With the improvement of product complexity, decision of product design will have a significant influence on the product development cycle, cost and performance [1,2]. In general case, the design of complex engineering objects, such as the design of complex customized products, is a complex multi-disciplinary and highly iterative process that involves the integration of multi-specialized information and the collaboration of multidisciplinary resource.

* Corresponding author. Tel.:+86 13588744698.
E-mail address: liuhaiqiang1980@126.com.

doi:10.1016/j.proeng.2011.11.2505

The design of complex customized product is still have great difficulty and intensity, because of the complicated process of product design and complexity of the relative isolation of the various design sub-processes, the lack of integration and collaboration in overall design process. Therefore, in order to solve the problem of data management, process integration and collaboration in the process of complex customized product design and to shorten the design development cycle and reduce product development costs, improve product development quality. This paper takes multidisciplinary collaborative design(Multidisciplinary Collaborative Design, MCD) process of complex customized product as the research object, the process integrated control method for multidisciplinary collaborative design was proposed based on building MCD-oriented Integration of Product Design Meta-model, fully considering the cooperative effect between design disciplines to minimize design iterations, and realizing information sharing and interchange between product design process and resources, the process integrated method can effectively get the product optimized design solution for collaborative design staff.

2. MCD-oriented Integration of Product Design Meta-model (MIDM)

Multidisciplinary collaborative design process, the various disciplines of design activities is the link information integration, information integration management objective is to integrate all aspects of information involved can meet the design goals of its own, if the model describes the inconsistency will lead to difficulties in collaboration, to the product of multidisciplinary collaborative design process adversely affect the integrated control [3,4]. MCD-oriented Integration of Product Design Meta-model--MIDM is a meta-model integration of multidisciplinary collaborative design for integrated product meta-model, process meta-model, knowledge meta-model, resource meta-model composed of four parts together, is a kind of abstract-level meta-model of integrated management model.

2.1. Basic Summary of Meta-model

References should be listed at the end of the paper, and numbered in the order of their appearance in the text. Meta-model is the description model, which is also about the basic concepts of the model, the basic relationship between the semantics of the basic constraints, the model can be described as specific models or specific objects. In layman's terms, meta-model is the model standards. Between the meta-model and model of the relationship with the instance of a class: each model is an instance of meta-model.

Compared with meta-model and model, meta-model has its own characteristics, as follows (Table 1):

Table 1. Major characteristic comparison of meta-model and model

Major Characteristic	Meta-Model	Model
Description	Description of model	Description of specific object
Dependence	Independence of model	Dependence of meta-model
Stability	Stable	Unstable
Sharing ability	Strong	Poor

2.2. Meta modeling Process of MIDM

Section headings should be left justified, with the first letter capitalized and numbered consecutively, starting with the Introduction. Meta modeling techniques used to establish the meta-model of integrated

products, integrated process meta-model, product meta-model, knowledge meta-model and resource meta-model composed of MIDM, must go through the following four phases: analysis phase of Meta-model, attributes creation phase of Meta-model, rules creation phase of Meta-model and checking phase of Meta-model.

（1）Analysis phase of Meta-model

Meta modeling techniques combined with the characteristics of the extraction of the implementation of the abstract model of integrated design, complete meta-model analysis. Analysis should include: product demand information of multidisciplinary collaborative design analysis, structural analysis of product components, collaborative design process and characteristics of the task analysis, multi-disciplinary analysis of knowledge acquisition, design objects and associated object analysis, object analysis, the scope and design rules .

（2）Attributes creation phase of Meta-model

Meta modeling techniques used to extract meta-attributes, which included the state for analysis. Subject knowledge for analysis, design objects and associated object analysis, object analysis, the scope and design rules.

（3）Rules creation phase of Meta-model

Meta-model through the establishment of effective rules of restraint, to reduce the redundancy models, element models to ensure the accuracy and effectiveness. Meta modeling following technical rules: the attribute definition rules of meta-model, generality rules, the execution rules, integration rules, modular rules and extensibility rules.

（4）Checking phase of Meta-model

Meta modeling is completed by the check of certain testing standards or specifications, its tests and analysis, to improve the model. Meta-model of the check process including content check, property evaluation, calibration and interface to the effectiveness of the implementation of rules of the inspection and so on, through constant iteration, repeatedly revised, and ultimately improve the meta-model.

The purpose of design and construction MIDM is to determine from requirements to conceptual design, overall design data in all stages of the process, knowledge acquisition, design and analysis tools and other information as well as the organic association between this information, the definition of an interdisciplinary, cross-phase global model.

2.3. Process Integrated Control Analysis for Multidisciplinary Collaborative Design

The objective architecture of product integrated control for multidisciplinary collaborative design consists of three parts: disciplinary design objective, design process objective and collaborative optimization objective. Disciplinary design objective is main guideline to implementation of multidisciplinary collaborative design, and can effectively guarantee for the design process objective and collaborative optimization objective; Design process objective is mainly lies in design process of coordination and control, the reduction of iterative times in design
process , minimize design cost and shorten design cycle and improve design quality; Collaborative optimization objective is mainly reflected in increasing response rate of customer requirements and meeting customer satisfaction degree of design process objective, and obtaining comprehensive optimized solution for product design.

Collaborative optimization strategy can be used in process integrated control for multidisciplinary collaborative design of complex customized product which is a multi-level optimization model. The strategy is collaborative design methodology based on decomposition in a typical double-layer optimization strategy and coordination, will coordinate the design parameters and multi-disciplinary collaborative design constraints of space are decomposed into several independent constraints, design

parameters allow the intersection of the sub-Various disciplines within the system level. Optimization of each subject being cut off the interaction with other disciplines, systematic optimization of the various disciplines in parallel, the design of the conflict between the various disciplines, from system-level consistency constraints to coordinated. Collaborative optimization strategy of design process integrated control shown in Figure 1.

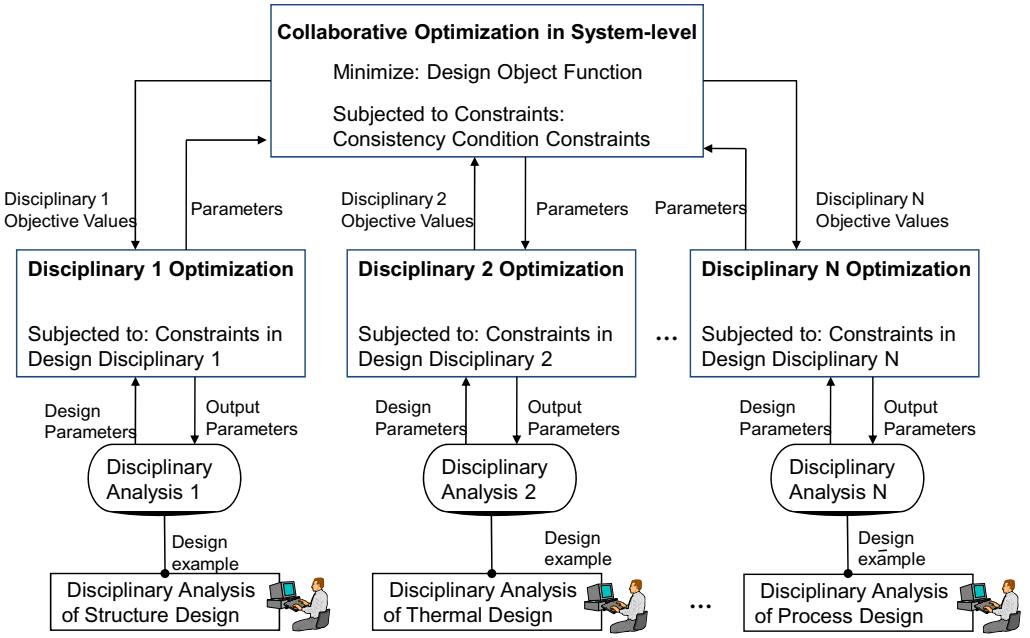

Fig. 1. Collaborative optimization strategy

2.4. Implementation method of process integrated control based on MIDM

Integrated control of the process of implementing rules describe the process of multidisciplinary collaborative design process information and implementation methods, the design objects under the guidance of the rules by MIDM instantiation, access to the complete product design model and application of design processes function Objects move, to express the static structure of design information that:

$$P(S)/MPC \rightarrow P_i(S)/MPC, \quad i=1,2,3,4 \tag{1}$$

In equation (1): $P(S)/MPC$ indicated matching degree of multidisciplinary collaborative design process that in the corresponding matching rules S described under the implementation of formal methods with the process of matching rules, respectively, $P_i(S)$ is corresponding to integrated product design model when the process model, knowledge model, resource model and product model ($i=1,2,3,4$), MPC standardized the formal description of the implementation process. Designers began to design, use of analogical reasoning is generally the model, the new design problems and compared to the previous design example, to choose the closest program to make the

appropriate changes as a design template, modify the process of deductive reasoning is usually The process, which involves the matching of design rules [5,6].

Based on the above implementation method, from design to search out the rules of design problems with the current task before the best matches the rule, if the rules do not meet the standard conclusion is that information on the implementation of the rules can be adjusted to achieve the integration of different models during the corresponding period effective control and management.

3. Application example

Industrial Steam Turbine are designed and manufactured according to customer orders of complex customized products, a business group in Hangzhou is the largest manufacturer of industrial steam turbine, its leading products - industrial steam turbine is widely used in petroleum, chemical, metallurgy, light industry, energy, building materials, textile and other industrial sectors. Industrial Steam Turbine is a typical technology-intensive and involves many disciplines products, product mix complexity, high reliability, and its main components requires high temperature, impact resistance and high precision, very suitable for multidisciplinary collaboration Application of the design process of integrated control. In this paper, a type of back pressure steam turbine industry, for example, in complex customized products have been developed for multi-disciplinary collaborative design management system integration platform, will be based on MIDM multidisciplinary collaborative design process for its implementation of integrated control of the design process.

Table 2. Overall design parameters of flow path

Design Parameters	Initial value	Lower limit	Upper limit	Optimal value
Inlet root diameter D_{oN} (cm)	230.0	220.0	245.0	234.6
Outlet root diameter D_{2N} (cm)	280.0	265.0	310.0	275.4
Max height of static blades h_{Lemax}(cm)	30.0	28.0	35.0	36.6
Min height of static blades h_{Lemin}(cm)	40.0	30.0	45.0	36.7
Circumferential velocity C_{ou} (cm/s)	48.5	42.0	65.0	52.4
Inlet enthalpy h_0 (kj/kg)	3196.5	3000.0	3500.0	3130.2
Inlet pressure pressure p_{0F} (Mpa)	3.35	3.80	2.00	2.43
Outlet pressure p_{2E} (Mpa)	1.96	1.60	2.30	1.72

Interdisciplinary collaborative design staff design and analysis flow passage refinement, the standard design element model of integrated modeling process, the constraints in the implementation of the rules regulating the level, the overall design parameters of the drum-level object, the object design model, input file object, the output file object and subject object property analysis tools, the description and configuration specific to establish MIDM meta-model, an instance of the different part of the design flow process, knowledge, personnel organization, design data, etc., if change drum of the design process, variable conditions accounting process and the corresponding design parameters, knowledge, personnel, parts model. The overall flow path design parameters shown in Table 2.

System administrators to MIDM into extensible markup language (eXtensible Markup Language, XML) language can describe the meta-model. To support the implementation of model-driven process, using the system model converter to import the platform described MIDM XML meta- model generation system platform models, have applied the prototype system metadata, and preliminary testing at the

design stage, driven through the concrete MIDM part of the integrated multidisciplinary collaborative design process control, shown in Figure 2.

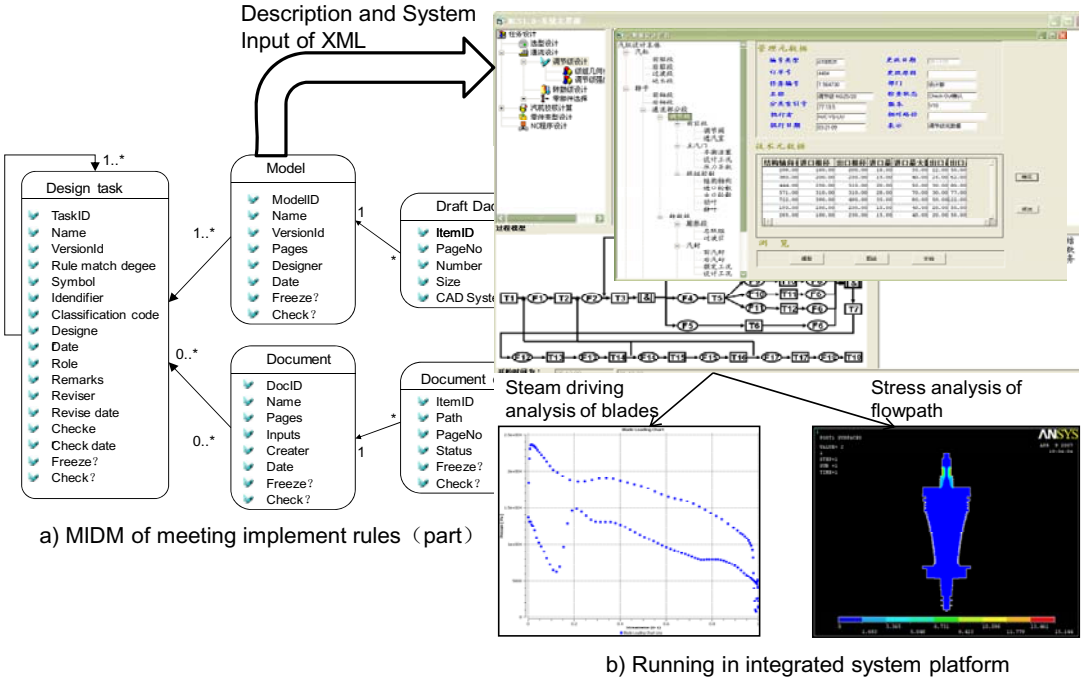

Fig. 2. Running instance of process integrated control for multidisciplinary collaborative design in system

4. Conclusions

Through deeply analyzing process integrated control of multidisciplinary collaborative design, from the product data, processes, knowledge and information resources, systems integration design point of view in product multidisciplinary collaborative design, MCD-oriented Integration of Product Design Meta-model(MIDM) was built, the process integrated control MIDM implementation methods was proposed based on MIDM, by means of MIDM, conducive to the process of product design and resource sharing and interaction, can provide complete multidisciplinary collaborative design process required of all applications geometric information and non-geometric information, including process data, model data and resource data. And in the analysis, research and application, based on the verification for multidisciplinary collaborative design process integration and design of information-sharing platform support provided methodological support and the effectiveness of the implementation of integrated control of the process that will follow the rules and characteristics of product design, multi-Subject collaborative process and data integration, to enhance the efficiency of product design, and ultimately enhance the market competitiveness of complex customized product.

Acknowledgements

This research was supported by Key Discipline of The Ocean Mechatronic Equipments Technology, National Natural Science Foundation of China(Grant NO.60873106 and NO. 60903087)

References

[1] HUANG Changlin, TAN Jianrong, ZHANG Shuyou: Multi-level configuration design method for complicated engineering-to-order product. Computer Integrated Manufacturing Systems, 1261-1267(2007).

[2] QI Guoning, GU Xinjian, TAN Jianrong: Mass customization technology and its application (Beijing:China Machine Press,2003).

[3] LI Xiangshuo, QI Guoning, LIU Haiqiang: Incremental-convergent method for development and implement of product lifecycle management system. Computer Integrated Manufacturing Systems, 13(12):2427-2432(2007).

[4] BATILL S M, STELMACK MA, YU X Q: Multidisciplinary design optimization of electric powered unmanned air vehicle. Aircraft Design, 2(1):1-18(1999).

[5] SHI Qi, DU Jiang, LI Yuan: ACBR (Case-Based Reasoning) Conceptual Design Model for Product Development. Journal of northwestern poly-technical university, 20(2): 203-207(2002).

[6] TAYLOR D A: Business engineering with object technology. Hoboken, N.J.， USA: John Wiley & Sons(1995).